REPORT DOCUMENTATION PAGE

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 20, 2000	Annual, December 1 1999 to November 30 2000

4. TITLE AND SUBTITLE
Wavelet Based Feature Extraction for Target Recognition and Minefield Detection

5. FUNDING NUMBERS
Grant No: N00014-99-1-0091
PR Number: 99PR01390-00
P.O. Code: 311

Disbursing Code: N68892
AGO Code: N66020
CAGE Code: 4B857
CFDA No: 12.300

6. AUTHORS
Barry G. Sherlock

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
University of North Carolina at Charlotte
9201 University City Boulevard
Charlotte, NC 28223

8. PERFORMING ORGANIZATION REPORT NUMBER
2975-99-0106 ANNUAL 2

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Dr. Wendy L. Martinez, ONR 311, Office of Naval Research, Ballston Center Tower One, 800 North Quincy Street, Arlington, VA 22217-5660

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
None

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is Unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The P.I. visited the Naval Surface Warfare Center (NSWC) in Dahlgren, VA, for one week in January to continue his established collaboration with NSWC personnel. In particular, the work with Ronald Gross on the development of a MATLAB demonstration suite, and with Dr. Addison Jump on wavelet theory, deserve mention. Details are given in Section II of the progress report. The collaboration with NSWC personnel has been particularly productive, both in regard to the work on this project and also to work in other areas of interest to the Navy.

The P.I. spent the summer months in South Africa, working at the Universities of Cape Town and Stellenbosch. Valuable collaborations were established with researchers at these two institutions, and plans are in place to obtain support from the South African Foundation for Research Development to obtain funding for their doctoral students to visit UNC-Charlotte, further solidifying the relationship between the P.I. and these universities.

Good progress has been maintained in completing tasks laid out in the proposal for this project, including a dramatic improvement in the speed of the wavelet transform software and several theoretical results of use to the project. Details are given in Section II of the progress report, and copies of publications are attached to the report.

14. SUBJECT TERMS
Target Recognition; Wavelets; Filter Banks; Stochastic optimization; Simulated Annealing; Discrete Transforms

15. NUMBER OF PAGES
4

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

20001124 158

DTIC QUALITY INSPECTED 4

Annual Progress Report on ONR Grant N000149910091

Title: **Wavelet-Based Feature Extraction for Target Recognition and Minefield Detection**

PI: Barry Sherlock
University of North Carolina at Charlotte
Charlotte, NC 28023
Phone (704)547-2722   Fax: (704)547-2352
email: sherlock@uncc.edu

I. Summary

This report covers the second year of the project (December 1, 1999 to November 30, 2000). During this period, in addition to the technical progress made upon the work described in the proposal, several new collaborations have been established. Ph.D. student Steven Moore had to leave North Carolina for personal reasons and is no longer working on the project. Instead, the grant has supported Masters' students who have done software development and some theoretical derivations. Since the last report, several publications have been produced, and are attached to this report.

The P.I. visited the Naval Surface Warfare Center in Dahlgren, VA, for one week in January to continue his established collaboration with NSWC personnel. In particular, the work with Ron Gross on the development of a Matlab demonstration suite, and with Addison Jump on wavelet theory, deserve mention. Details are given in section II. The collaboration with NSWC personnel has been particularly productive, both in regard to the work on this project and also to work in other areas of interest to the Navy.

The P.I. spent the summer months in South Africa, working at the Universities of Cape Town and Stellenbosch. Extremely valuable collaborations were established with researchers at these universities, and plans are in place to obtain support from the South African Foundation for Research Development to obtain funding for their doctoral students to visit UNC-Charlotte, further solidifying the relationship between the P.I. and these institutions.

II. List of Research Accomplishments:

The following work was completed during the past year:

1. The P.I. visited the Naval Surface Warfare Center in Dahlgren, VA, for one week in January to continue his established collaboration with NSWC personnel (see items 2 and 3 below).

2. In collaboration with Dr. Addison Jump at the Naval Surface Warfare Center, work is in progress on determining parameterizations of orthonormal wavelets having a specified order of regularity. A partial solution to the problem has been found and will be presented at the AeroSense 2001 conference in Florida. A full solution to this problem would be of much use in Naval signal processing as it would allow one to generate wavelets which are optimal for one's given application. [Task 2:ii].

3. Collaboration with Ron Gross of the Naval Surface Warfare Center continues, in developing (in Matlab) a software suite to be used to demonstrate the algorithms that will be produced during the research on this project. This demonstration suite is being extended and enhanced as more algorithms are developed.

4. The P.I. visited South Africa from mid May to mid August, working at the Universities of Cape Town and Stellenbosch. Valuable collaborations were established with the following researchers at these universities:

   - Dr. Gerhard de Jager, Professor of Signal Processing in the Department of Electrical Engineering at the University of Cape Town.

   - Dr. Johan du Preez, Professor of Signal Processing in the Department of Electrical Engineering at the University of Stellenbosch.

   - Dr. Ben Herbst, Professor of Applied Mathematics at the University of Stellenbosch.

   All three of these researchers are enthusiastic to extend and continue our collaboration because we found that our different skills complemented each other well, and we are sure that our collaboration will be highly productive in the years ahead. For instance, Drs. de Jager and du Preez are experts in pattern recognition, which is exactly what the P.I. needs in order to properly apply his knowledge of wavelet theory and signal processing to problems involving target recognition. Dr. Herbst is an accomplished applied mathematician whose expertise will be valuable in solving several problems in wavelet theory on which the P.I. is working. Plans are in place to obtain support from the South African Foundation for Research Development (FRD) to obtain funding for their doctoral students to visit UNC-Charlotte, further solidifying the relationship between the P.I. and these institutions.

5. A collaboration between the P.I. and Dr. Y.P. Kakad, Professor of Electrical and Computer Engineering at UNC-Charlotte has been established. Dr. Kakad provides expertise concerning the hardware implementation of algorithms developed by the P.I. The collaboration has been fruitful, resulting in several publications, some of which are listed in Section IV below.

6. Presentation of two-day intensive course entitled "Wavelets and Filter Banks" (July 18 and 25), Department of Electrical Engineering, University of Cape Town, South Africa. Attendees included university faculty, graduate students, and engineers and scientists from industry who came from various parts of the country to attend.

7. Presentation of two-day intensive course entitled "Wavelets and Filter Banks" (May 22-23) to faculty and graduate students, Department of Electrical Engineering, University of Stellenbosch, South Africa.

8. Seminar entitled "Fingerprint Image Enhancement", given at the Department of Electrical Engineering, University of Stellenbosch, South Africa, August 4.

9. Refinement of the Discrete Wavelet Transform in one and two dimensions in MATLAB. In the original version of these algorithms, the inverse transform was considerably slower-running than the forward transform. After a detailed analysis of the performance of these algorithms, improvements were implemented which sped up the forward and inverse transforms by factors of 2 and 20, respectively. [Task 1:iii]

10. The P.I. has found a method to generate the space of biorthogonal wavelets having specified order of regularity. The technique works for both odd and even-length wavelets. Implementations have been written for a few special cases, but the implementation of the general case is not yet complete. [Task 2:vi,vii].

11. The P.I. has derived theoretical expressions for the frequency and spatial dispersions of any FIR filter in terms of the coefficients of its impulse response. [Task 3a:i]

12. A series of orthonormal wavelet filters has been generated, each optimized for a different trade-off between frequency and spatial dispersions (i.e. having 'balanced uncertainty'). [Task 3b].

III. Students:

The following graduate students performed work on this project during the period covered by this report:
1. **Steven Moore**, Ph.D. (Elec.Eng.) student. The project formed the subject of Mr. Moore's Ph.D. research work. Mr. Moore left UNC-Charlotte in August.
2. **Leroy A. Calder**, M.S.E.E. student. Mr. Calder developed Matlab software in support of the research work of the P.I. and the Ph.D. student.
3. **Osama Abu-Sharkh**, M.S.E.E. student. Mr. Abu-Sharkh is assisting with the derivation of fast transform algorithms.

Because Mr. Moore chose to be self-supporting during the past year, it was possible to support the two M.S.E.E. students instead.

IV. Publications:

The P.I. has published the following papers during the period covered by this progress report. Each paper contains a statement of acknowledgement of support from ONR.

Published Dec. 99- Nov. 00:
1. B.G. Sherlock and Y.P. Kakad, "Windowing the Discrete Cosine Transform in the Transform Domain", published in Advances in Physics, Electronics and Signal Processing Applications, World Scientific and Engineering Society Press, 2000, ISBN 960-8052-17-3, pp. 320-324.
2. H.H. Mu, Y.P. Kakad and B.G. Sherlock, "Artificial Neural Network Based Controller Design for Advanced Aircraft", *14th International Conference on Systems Engineering (ICSE 2000)*, Coventry, England, September 2000.
3. B.G. Sherlock and Y.P.Kakad, "Windowing the Discrete Cosine Transform in the Transform Domain", *4th World Multiconference on Circuits, Systems, Communications and Computers (CSCC'2000)*, Athens, Greece, July 2000 (paper number 126).

4. Hong Helena Mu, Y.P. Kakad and B.G. Sherlock, "Application of Artificial Neural Networks in the design of Control Systems", *16th Annual Conference on CAD/CAM, Robotics and Factories of the Future (CARS&FOF'2000)*, Trinidad, June 2000.
5. A.B. Jump and B.G. Sherlock, "Wavelets of Arbitrary Order of Regularity", *SPIE 14th Annual International Symposium on Aerospace/Defense Sensing, Simulation, and Controls (AeroSense 2000)*, Orlando, Florida, April 2000. Published in *Proceedings of SPIE*, Volume 4056.

Under review:
6. B.G. Sherlock and Y.P.Kakad, "Transform Domain Technique for Windowing the DCT and DST", submitted April 2000 to *Journal of the Franklin Institute* (paper number JFI/2000/200058).
7. B.G. Sherlock and Y.P.Kakad, "Windowed Discrete Cosine and Sine Transforms for Shifting Data", submitted April 2000 to *Signal Processing*, (paper number 1372).
8. B.G. Sherlock and Y.P. Kakad: "Rapid update of Discrete Fourier Transform for Real-Time Signal Processing", submitted to *SPIE's 15th Annual International Symposium on Aerospace/Defense Sensing, Simulation, and Controls (Aerosense 2001)*, Orlando, Florida, 2001.
9. B.G. Sherlock and Y.P. Kakad, "Rapid Prototyping of Update Algorithm of Discrete Fourier Transform for Real-Time Signal Processing", submitted to *SPIE's 15th Annual International Symposium on Aerospace/Defense Sensing, Simulation, and Controls (Aerosense 2001)*, Orlando, Florida, 2001.
10. B.G. Sherlock and A.B. Jump, "Towards a Parameterization of Orthonormal Wavelets of Arbitrary Regularity", submitted to *SPIE's 15th Annual International Symposium on Aerospace/Defense Sensing, Simulation, and Controls (Aerosense 2001)*, Orlando, Florida, 2001.
11. B.G. Sherlock and I.R. Jones, "Adapting traditional teaching methods to the Distance Learning environment", submitted to *Annual American Society of Engineering Education Conference (ASEE 2001)*, Albuquerque, New Mexico, June 2001.

V. Presentations:

1. Two-day intensive course entitled "Wavelets and Filter Banks" (July 18 and 25), Department of Electrical Engineering, University of Cape Town, South Africa. Attendees included university faculty, graduate students, and engineers and scientists from industry who came from various parts of the country to attend.
2. Two-day intensive course entitled "Wavelets and Filter Banks" (May 22-23) to faculty and graduate students, Department of Electrical Engineering, University of Stellenbosch, South Africa.
3. Seminar entitled "Fingerprint Image Enhancement", given at the Department of Applied Mathematics, University of Stellenbosch, South Africa, August 4.